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RESONANCES OF A ROTOR/STATOR CAVITY IN THE VICINITY OF THE CRITICAL POINT OF SF_6

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The extreme hydrodynamic regimes of spatial turbo-pumps are sources of complex phenomena which can be critical to their operation: appearance of instabilities, excitation of vibrational modes, new sources of dissipation and heat transfer. Thus, understanding and accurately predict the hydrodynamics in industrial rotating systems play a key role in the estimation of the reliability and the performances of these machines. To achieve the very high Reynolds numbers (10^7 to 10^8) of these flows and also to highlight the resonances of cavity modes induced by the compressibility of the fluid, we performed an experimental study of a rotor/stator flow using sulfur hexafluoride (SF_6) near its critical point as a working fluid. SF_6 is an inert gas whose critical temperature and pressure are 45.5 C and 37.6 bar. These thermodynamics conditions are sufficiently accessible to allow a laboratory experimental study. Near critical points, the behavior of fluids density with pressure is singular and a substantial reduction in the speed of sound is usually observed. For SF_6, values as low as 73 m/s are possible if pressure and temperature are sufficiently close to their critical values. This high compressibility should thus permit to explore typical compressible phenomena such as cavity resonances. Moreover, the kinematic viscosity of SF_6 in its liquid phase allows us to gain at least a factor 20 on the value of the Reynolds number relatively to water. This gain has allowed us to reduce the size of the facility. Consequently, the rate of rotation of the rotor could be significantly increased compared to conventional systems in water in order to reach Reynolds numbers above 10^7 that is close to the industrial case but also to reach the range of the cavity mode frequencies where resonances are expected. The aim of our experimental study is thus to investigate and if possible, simulate the vibrations present in spatial turbo-pumps rotor/stator cavities. In particular, we expect to determine the different characteristics of the cavity modes for a fluid layer between a rotor and a stator. A Helmholtz type theoretical model is first derived and shows that the characteristic frequencies of these modes change with the square root of the pressure in the fluid. From an experimental point of view, a rotor/stator cavity with its motor (maximum speed 12,000 rpm) is inserted into a pressure vessel. This vessel is thermalized by circulating water from a thermostatic bath. The stator is mounted on an elastic membrane that allows its motions in the axial direction and an accelerometer can record its vibrations. The first experiment is devoted to the detection of the different vibration modes of the cavity using an electromagnet and a spring that initially pushed up the stator before releasing it suddenly. The stator then oscillates freely and we can record its damped vibrations by the use of the accelerometer. This experiment is conducted for various pressures of SF_6 and for a fixed temperature of 45 C. The fundamental mode of vibration can be easily detected by comparison with the theoretical model. However, we show that we should take into account in the model a fluid added mass (by 40 times the mass of fluid in the cavity). This added mass is our only free parameter and our measurements confirm the existence of the cavity mode as described by the Helmholtz type resonator model. The second step in the experimental study is to excite directly the cavity mode by the motions of the fluid through the rotation of the rotor. As expected, during the passage of the rotation frequency through the mode frequency band, a resonance peak is perfectly observed. As projected in this study, it appears that the rotation of the stator can indeed excite pressure fluctuations in the cavity which in turn can cause the resonance of the compressible fluid layer between the stator ad the rotor. Thus, although it seems not necessary to take into account the fast and highly turbulent rotating flow (the Mach number of the flow is a few tenths) we prove that the compressibility of the fluid plays however a key role in the mechanical behavior of the rotor/stator cavity.